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MELBOURNE, VICTORIA

REPORT

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VISCOSITY MEASUREMENTS OF MALLEABLE EXPLOSIVE (MEX), A NEW DEMOLITION EXPLOSIVE

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ABSTRACT

The rheological characterisation of Malleable Explosive (MEX), a new explosive intended for demolition use, is presented. A Brookfield viscometer with T-bar spindles and Helipath stand is used to investigate the viscosity of MEX at shear rates similar to those encountered during extrusion of the material from a dispenser. The indicated viscosity is sensitive to the position, type and speed of spindle used for the determination. The viscosity is determined over the temperature range -16°C to 60°C and is particularly temperature sensitive only below 0°C, whereupon the viscosity rises rapidly. From 0°C to 40°C, the viscosity decreases to a value which is dependent upon the temperature and shear rate, then remains constant or increases slightly with further heating to 60°C. A laboratory method suitable for transfer to the production factory in the event that MEX proceeds to full production, is detailed.

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CONTENTS

VISCOSITY MEASUREMENTS OF MALLEABLE EXPLOSIVE (MEX), A NEW DEMOLITION EXPLOSIVE

1. INTRODUCTION

A regiment of the Australian Army requested Materials Research Laboratories (MRL) to provide (or recommend) an explosive which a soldier in the field could readily extrude into and onto complex demolition targets. MRL produced a new low viscosity plastic explosive (LVPE) which was of a toothpaste-like consistency and remained in place when dispensed onto a range of vertical surfaces [1]. Army subsequently tasked the Office of Defence Production (ODP) to develop the material, produce a small lot and package it in 100 g dispensers for field evaluation (see Fig. 1). Army designation for this material is Malleable Explosive (MEX) and the anticipated service temperature range for its use is $0^{o}C$ to $60^{o}C$.

A Material Specification for MEX was drafted [2] to guide development of the material at Explosives Factory Maribyrnong (EFM). The Draft Specification contained a description of a number of appropriate tests and listed acceptable levels for each test; these were based on results for MRL-produced MEX. The viscosities of initial EFM mixes of MEX showed considerable variation, with a number of mixes outside the viscosity range cited in the Draft Specification [1,2] even though results for other tests were within acceptable limits. Since it appeared that acceptance of MEX would depend critically on the results of viscosity measurements, experiments were undertaken to evaluate the effect of changing the measuring technique on the viscosity reading. In addition, the effect of temperature on MEX viscosity was investigated.

A primary aim of this work was to develop a laboratory method which could be easily transferred to a production factory if this explosive (or another explosive with similar flow properties) proceeded to full production. Of particular interest was the measurement of material properties under conditions which could be related to the extrusion of MEX from a dispenser at service temperatures.

2. ESTIMATION OF SHEAR RATE DURING EXTRUSION OF MEX

A minidispenser is shown schematically in Figure 1 with pressure being applied to a piston to cause extrusion of material from the nozzle. The equation which governs steady state laminar flow through a capillary orifice is,

$$D = \frac{4Q}{\pi R^3} \qquad (1)$$

where, D is the shear rate (s^{-1})

Q is the flow rate (cm^3/s)

R is the outlet radius (cm),

and the linear flow rate L is $Q/\pi R^2$ in cm/s, so D = 4L/R. For MEX, the minimum diameter to be extruded is likely to be 0.6 cm (R=0.3) since this is close to the unconfined failure diameter of the explosive [1,2]. User trials and experience at MRL have shown practical linear rates of dispensing MEX to be less than about 2 cm/s (L=2). Faster extrusion rates make emplacement of the material more difficult, particularly on complex demolition targets, and lack of adhesion to the target can be a problem. A realistic upper limit for shear rate during application of MEX was therefore calculated to be about 25 s^{-1}. Similarly, assuming L_{min} = 0.2 cm/s and d_{max} = 1.0 cm (R = 0.5) a minimum shear rate of about 1.6 s^{-1} was derived (see Fig. 1). It should be noted that this calculated shear rate is only approximate because equation (1) only applies when a Newtonian fluid flows through a capillary in the absence of slip.

3. VISCOSITY MEASUREMENTS

A range of commercial viscometers is available for the characterisation of the rheology of toothpaste-like materials. A model HBTD Brookfield viscometer, with Helipath* stand and T-bar spindles, was selected for this work because the problem of "channeling", which sometimes occurs in materials which possess a yield stress when investigated with conventional viscometers, was eliminated by virtue of the downward moving helipath stand which permits the spindle to cut continuously into fresh sample. Cleaning of the spindles and cup was also a simple matter since no narrow apertures or close tolerances were present in their design. Additionally, temperature control was easily achieved by means of a jacketed vessel or by conditioning the sample in a

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* The Helipath stand allows the viscometer to lower as the spindle rotates, so the path travelled by the spindle tip is helical (see Fig. 2) and the spindle cuts fresh material all the time.

controlled temperature bath. Furthermore, the Brookfield viscometer was considered suitable for the quality control testing of MEX by factory personnel because of its ease of operation and its relatively low price.

Parallel plate plastometry was considered unsuitable because of the low yield stress of MEX; larger samples of the material are prone to slump.

Rotational viscometry was considered inappropriate since MEX was grease-based and the composition, like greases, was expected to be thixotropic*. A rotational viscometer would therefore cause a reduction in the viscosity of the material as it was consistently being sheared between the coaxial cylinders of the viscometer. It was considered desirable to try to exclude the effects of thixotropy since this was unlikely to be important for extruding MEX from a dispenser. Only slight shear would occur during movement of MEX up the dispenser, with most shear occurring at the nozzle. Thixotropy is of course relevant to mixing and loading of MEX into dispensers and to the properties of the material after dispensing. In addition, the profiled sensor systems of rotational viscometers have been known to "fracture" and "channel" materials with a high solids content like MEX when sheared, although rotational viscometers can be used to determine a static property such as the yield stress when used with a vane rotor. Furthermore, a method based on rotational viscometry would probably be unsuitable as a production test.

Capillary viscometry was considered to be an appropriate method which a production facility could readily perform. Acceptance of Australian Plastic Explosive No. 4 (PE4) into service depended at one time on the results of an extrusion test [3,4]. However, laboratory work at sub-ambient temperatures would have been more difficult, cleaning would have been more difficult and the close tolerances for sliding metal surfaces in, for example, the Instron Capillary Rheometer, posed a potential safety hazard.

3.1 Apparatus

During the initial formulation study [1], a Brookfield model RVT viscometer, with T-F spindle, was used to assess the viscosity of MEX at 20 ± 2°C. Approximately 160 g of MEX in a 100 ml glass beaker was used. (See Appendix 1).

The work reported here was conducted with a Brookfield model HBTD viscometer which has a "stiffer" measuring spring than the model RVT; only small (inaccurate) readings of viscosity could consequently be recorded with the T-F spindle. Therefore, other spindles were used (see Table 1), and because they were larger, larger MEX samples were required.

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* Thixotropy is the reduction in viscosity of a material with time, during application of constant shear.

Approximately 400 g of MEX was gently tamped into a jacketed glass vessel with an internal diameter of 86 mm. The vessel was connected to a controlled temperature bath. To investigate wall effects, measurements were made near the edge of the sample in a 100 mm diameter polyethylene jar. The jar containing MEX was immersed directly into the bath for 3 h prior to measurements. Temperatures were measured with a thermocouple immersed in the MEX sample to a depth similar to the spindle depth when the viscosity reading was taken.

The effect of temperature, position of spindle and type and speed of spindle on the indicated viscosity of MEX was assessed. Except where noted otherwise, the viscosity was measured when the spindle was at a depth of 29 mm in the sample, which had a total height of 45 mm.

The manufacturer of the viscometer claims that results obtained at less than 10% of range are unreliable and should be interpreted with caution. Furthermore, many readings exceeded the range of the viscometer. These results are indicated in the tables of results by asterisks; * for results in the unreliable range and ** for results which exceeded the range of the viscometer.

3.2 Shear Rate Approximation

For most viscometers the shear rate is accurately defined by the geometry and speed of a moving sensor or the exit velocity of material from an accurately measured capillary. The Brookfield viscometer, with T-bar spindle and Helipath stand, produces a complex shear field which does not allow for accurate calculation of the shear rate. However an approximate shear rate has been calculated by analogy with rotational viscometry. In a co-axial cylinder system used for rotational viscometry, the shear rate D is given by,

$$D = 2\omega \frac{R_a^2}{R_a^2 - R_i^2} \tag{2}$$

where, ω is the angular velocity (s^{-1})
R_a is the radius of the cup (cm)
R_i is the radius of the sensor (cm)

Furthermore, the angular velocity ω is given by

$$\omega = \frac{2\pi n}{60} \tag{3}$$

where n is the rotor speed in revolutions per minute (rpm).

An indication of the movement of a T-bar spindle in MEX, using the Brookfield viscometer and Helipath stand, is given in Figure 2. Assuming the spindle to be cylindrical and R_a = 1.2 cm and R_i = 1 cm*, and ignoring the vertical motion of the spindle, a T-D spindle rotating at 50 rpm yields a shear rate of about 35 s^{-1} which is higher than the maximum shear rate calculated for extrusion of MEX (Section 2).

We therefore believe that the shear rate of MEX during extrusion from a dispenser can be approximated using the Brookfield Viscometer with T-bar spindles and Helipath stand.

4. MATERIALS

Two batches of MEX were investigated. One was EFM composite Batch 87/1 which was assessed as suitable for specialist demolition work while the other was EFM MEX Mix 15 which was considered to be too viscous for easy extrusion (with hand pressure) and was being considered for conventional Explosives Ordnance Disposal (EOD) use [5]. These are called batch A and B respectively in the following discussion.

5. RESULTS AND DISCUSSION

5.1 Comparison of Two Batches of MEX

Table 2 shows a comparison of the viscosity of the two batches of MEX at 20°C. Under identical measuring conditions, MEX batch B is about twice as viscous as batch A. As reported previously [1], MEX viscosity decreases with spindle speed, has a yield point and recovers its viscosity with time after the cessation of rapid stirring. A number of variations on the experimental technique were employed to examine the variation on the indicated viscosity of MEX batch B.

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* R_i was taken to be half the length of the T-D spindle's crosspiece. R_a was assumed from a comparison of measurements of indicated viscosities of MEX near the edge of the container and in the centre of the sample; when the spindle came within about 2 mm of the edge, the indicated viscosity was seen to rise.

5.2 Effect of Horizontal Position of Spindle on the Indicated Viscosity of MEX at 20°C

Table 3 summarizes the results obtained when T-B and T-C spindles were used to measure the viscosity of MEX (at 20 ± 2°C) both in the centre of the sample and near the container wall. For larger spindles such as T-B, a significant "wall effect" was observed; a 100% increase in viscosity was indicated. The smaller T-C spindle showed an increase of up to 10% at low spindle speeds. This suggests that consideration should be given to the sample dimensions when measuring MEX viscosity with large spindles, particularly at low spindle speeds.

5.3 Effect of Immersion Depth of T-C Spindle on the Indicated Viscosity of MEX at 20°C

Table 4 summarizes the results obtained when a T-C spindle was used to progressively measure the viscosity of MEX (at 20 ± 2°C) in the centre of the mix, as a function of the depth of spindle into the sample. Clearly, the indicated viscosity increases as the spindle immerses further into the sample for spindle speeds of 5, 10 and 20 rpm. This increase lies between 20-35% in the immersion depth range of 11-34 mm, depending on the spindle speed. The reasons for this increase are not clear. The explosive filler does not sediment in the binder, and the additional torque caused by immersion of additional spindle stem is expected to be small. The increase is probably due to bottom effects and/or thixotropic recovery of the sample since it is gently tamped between measurements.

For viscosity measurements on various batches of MEX there should be sufficient material beneath the spindle so that end/bottom effects are reduced and readings should be taken at a consistent depth of immersion of the spindle in the sample. As stated in Section 3.1 a consistent height of sample of 45 mm has been used for the other work reported here and measurements were made when the spindle was at 29 mm depth.

5.4 Effect of Temperature and Spindle Type and Speed on the Indicated Viscosity of MEX

Table 5 shows measurements of MEX viscosity over the temperature range of -16°C to 60°C, with a range of T-bar spindles. As reported previously [1], the viscosity of MEX decreases with increased spindle speed. It can be seen that the appropriate spindle depends on the MEX temperature. For example, results were able to be obtained on MEX at -16°C with only T-E and T-F spindles (at all spindle speeds), whereas at 60°C a complete set of results could only be obtained with the larger spindles T-B, T-C and T-D. For this batch of MEX, which is more viscous than other batches, the use of a T-D spindle would be recommended for measurements at 20°C. Other batches of MEX normally require a T-C spindle, as shown earlier in Table 2. With only a few exceptions the indicated viscosities of MEX listed in Table 5 increase with a reduction of the size of the spindle (from T-A through T-F), at fixed spindle speed. This is because larger spindles achieve higher shear rates and the material is less viscous at higher shear rates.

It is interesting to note that the difference in indicated viscosity of MEX at 20°C, using T-C and T-F spindles at 20 rpm, is about 25%. As described earlier in Section 3.1, MRL-produced formulations were assessed with a T-F spindle at 20 rpm. In the development of Draft Specification limits an acceptable viscosity range of 100-200 Pa.s was chosen. Subsequently, during development work at EFM, a shift to the HBTD viscometer forced a change from the T-F to the T-C spindle, without correction to the Draft Specification limits. It can be seen from Table 5 that material produced at EFM which was at the top end of the specified viscosity range (and was considered acceptable) was probably more viscous than the MRL-produced material and may have been considered unsuitable if there had been no change in viscometer model.

Some of the results from Table 5 are presented in another way in Table 6 so that the variation in indicated MEX viscosity with temperature is apparent. It can be seen that the viscosity of MEX decreases as the temperature increases from -16°C to 40°C. With only a few exceptions the viscosity appears to remain constant or increases slightly on heating MEX from 40°C to 60°C, suggesting that degradation of grease or loss of plasticizer has occurred during the conditioning period prior to test. The Australian Army requires that MEX is usable between 0°C and 60°C. Cooling from 60°C to 0°C causes an increase in indicated viscosity to a value about 50-300% higher, depending on the spindle type and speed used. Fortunately, the viscosity does not rise appreciably until the material is cooled below 0°C; the viscosity increases 2-4 fold on cooling from 0°C to -16°C.

The temperature control during routine viscosity measurements of MEX has been specified as 20 ± 2°C (See Appendices 1 and 2). It can be seen from Table 6 that when using a T-D spindle at 20 rpm to measure the viscosity of MEX between 0°C and 40°C the viscosity decreases almost linearly at the rate of about 18 Pa.s per 2°C. The temperature control cited therefore allows an error of ±5% in the indicated viscosity of MEX at 20°C and this should be taken into account during performance of a routine production test.

5.5 Effect of Lapsed Time Between Production of MEX and Measurement of Viscosity on the Indicated Viscosity

Table 7 shows the results of viscosity of MEX measured 3 and 7 days after production. The results are similar and the viscosity is about 6% less at a spindle speed of 20 rpm. This variation is consistent with the higher sample temperature achieved during conditioning prior to measurement after 7 days. As seen in the previous Section, a 2°C variation causes about a 5% change in viscosity.

6. CONCLUSIONS AND RECOMMENDATIONS

This work has shown that the indicated viscosity of MEX is sensitive to the position, type and speed of spindle used for the determination. To reduce variations in measurement technique it is recommended that a Brookfield model HBTD viscometer

equipped with a T-C spindle be used to assess standard MEX, and a T-D spindle to assess more viscous MEX, at 20°C. The measurement must be conducted at a constant spindle depth and uniform height and diameter of sample. It is recommended that sample dimensions of 100 mm diameter and 45 mm height be used and that a viscosity reading be taken when the spindle is at 30 mm depth.

The shear rate during extrusion of MEX from a dispenser has been calculated to be in the range 1-25 s^{-1}. It was also shown that this shear rate range is achievable using the Brookfield viscometer with standard spindles. For example, it was calculated that a T-D spindle rotating at 50 rpm would shear MEX at approximately 35 s^{-1}. For a production test it is recommended that a viscosity reading of MEX should be taken at a spindle speed of 20 rpm at 20 ± 2°C. A prescribed method is drafted at Appendix 2. To take account of the change in instrumentation the acceptable range should be changed to 100-180 Pa.s.

The temperature control cited is ± 2°C. This allows for an error of ±5% in indicated viscosity of MEX at 20°C. MEX viscosity is not particularly temperature sensitive except when it is cooled below 0°C, where it rises rapidly. Slightly out-of-Specification batches should be retested with more precise temperature control.

MEX was not observed to thicken appreciably between 3 and 7 days of production so the standard practice used for other explosives of sending samples for laboratory analysis within a few days of production is satisfactory for MEX.

The viscosity of MEX seems to vary with time of application of shear and this time dependence should be investigated more thoroughly with rotational viscometry to characterize the viscosity of MEX after mixing at the plant and after extruding from a dispenser in the field.

Reasons for the apparent increase in indicated viscosity of MEX when it is heated from 40°C to 60°C should be investigated further. Work is currently in progress to monitor a range of properties of MEX, including viscosity, after accelerated ageing.

7. REFERENCES

1. Parry, M.A. and Pitt, A.M. "A Low Viscosity Plastic Explosive for Specialist Demolition Use" (U), MRL- (in preparation) (Restricted).

2. Parry, M.A., Lee, J. and Bocksteiner, G. "Development and Characterisation of MEX and Comparison with the Properties of MRL-Produced Material," MRL-R- (in preparation).

3. Jones, W.T. (1986). "An Extrusion Method for the Measurement of the Plasticity of Plastic Explosive", RARDE Memo 48/68.

4. Ministry of Defence (1968). Defence Standard 07-10/Issue 1/22nd August 1968, "Plastic Explosive No. 4."

5. Winter, P.D. (1986) Explosive Ordnance Disposal Trial - Marrangaroo November 1986 (U) (Restricted).

TABLE 1

Dimensions of T-Bar Spindles Used

Spindle	Crossbar Length (mm)
T-A	48.1
T-B	36.4
T-C	27.1
T-D	20.4
T-E	15.3
T-F	10.9

TABLE 2

Comparison of Indicated Viscosity of Two Batches of
MEX at 20 ± 2°C Using T-C Spindle and Identical Measuring Technique

Spindle Speed (rpm)	Batch A (Pa.s)	Batch B (Pa.s)	Viscosity B/Viscosity A
0.5	1920	4088	2.12
1.0	1218	2760	2.27
2.5	690	1512	2.19
5.0	405	960	2.37
10.0	240	582	2.43
20.0	155	350	2.26
50.0	101	** 160	greater than 1.58

Batch A is EFM Composite Blend 87/1 and is characteristic of acceptable product and is similar to MRL-produced material.

Batch B is EFM mix 15.

TABLE 3

Effect of Horizontal Position of T-B and T-C
Spindles on Indicated Viscosity of MEX at 20 ± 2°C

Spindle Speed (rpm)	Centre of Mix Viscosity (Pa.s)		Viscosity Near Edge (Pa.s)	
	T-B	T-C	T-B	T-C
0.5	2912	3560	** 6394	3813
1.0	1760	2300	** 3197	2613
2.5	902	1160		1387
5.0		756		827
10.0		462		497
20.0		298		300
50.0		155		157

TABLE 4

Effect of Immersion Depth of T-C Spindle on the Indicated Viscosity of MEX at 20 ± 2°C, at Various Spindle Speeds

Spindle Depth (mm)	Indicated Viscosity (Pa.s) using T-C Spindle at a Spindle Speed of:			
	20 rpm	10 rpm	5 rpm	0.5 rpm
6.4	232	256	608	4800
7.5	232	-	-	
8.7	252	400	736	-
9.8	256	-	-	-
11.0	268	448	768	-
12.1	276	-	-	-
13.3	284	464	768	-
14.5	292	-	-	-
15.6	300	464	768	-
16.8	304	-	-	-
18.0	308	472	800	-
19.1	312	-	-	-
20.3	316	480	800	-
21.4	324	-	-	-
22.6	328	496	832	-
23.7	332	-	-	-
24.9	336	512	864	-
26.1	340	-	-	-
27.2	344	512	880	-
28.4	348	-	-	-
29.5	356	520	896	4160
30.7	356	-	-	-
31.9	360	536	928	-
33.0	368	-	-	-
34.2	372	544	944	-
35.3	376	-	-	-
36.5	-	568	992	-
38.8	-	584	-	-

TABLE 5

Indicated Viscosity of MEX (With Various Spindles)
at Temperatures Between -16°C and 60°C

Temperature (°C)	Spindle Speed (rpm)	Indicated Viscosity of MEX (Pa.s) Using Various Spindles					
		T-A	T-B	T-C	T-D	T-E	T-F
-16 ± 2	0.5	**	** 6394	13000	13040	12600	13600
	1.0			** 7992	9600	10600	11600
	2.5				5856	6000	8960
	5.0				** 3197	4280	5600
	10.0					2460	3240
	20.0					1450	1600
	50.0					600	576
0 ± 2	0.5	** 3197	3792	4880	4560	* 7800	*
	1.0		2672	3560	3320	5500	
	2.5		** 1279	1936	1824	5120	
	5.0			1264	2192	1960	
	10.0			** 799	904	1420	
	20.0				560	755	
	50.0				288	316	
20 ± 2	0.5	** 3197	3344	4088	3840	* 4280	* 4000
	1.0		2232	2760	2640	* 3340	* 3400
	2.5		1174	1512	1568	1960	* 2160
	5.0		** 639	960	1000	1160	* 1144
	10.0			582	612	780	* 740
	20.0			350	374	470	440
	50.0			** 160	204	240	212
40 ± 2	0.5	**	2320	2840	* 2960	* 3320	* 2880
	1.0		1440	1880	2080	* 2480	* 2400
	2.5		742	936	1056	* 1408	* 1392
	5.0		445	568	616	880	* 832
	10.0		269	324	372	490	* 468
	20.0		** 160	208	198	265	* 274
	50.0			118	117	146	* 139
60 ± 2	0.5	2904	3136	4480	3280	* 4240	*
	1.0	** 1599	1920	2700	2400	* 2800	
	2.5		922	1312	1072	1760	
	5.0		502	636	576	820	
	10.0		264	338	316	410	
	20.0		153	194	208	215	
	50.0		64	107	94	118	

TABLE 6

Indicated Viscosity of MEX at Temperatures
Between -16°C and 60°C, Using T-C, T-D and T-E Spindles

Spindle Speed (rpm)	Spindle Type	Indicated Viscosity of MEX (Pa.s) at Temperatures of:				
		-16 ± 2°C	0 ± 2°C	20 ± 2°C	40 ± 2°C	60 ± 2°C
0.5	T-C	13000	4880	4088	2840	4480
1.0		** 7992	3560	2760	1880	2700
2.5			1936	1512	936	1312
5.0			1264	960	568	636
10.0			** 799	582	324	338
20.0				350	208	194
50.0				** 160	118	107
0.5	T-D	13040	4560	3840	* 2960	3280
1.0		9600	3320	2640	2080	2400
2.5		5856	1824	1568	1056	1072
5.0		** 3197	2192	1000	616	576
10.0			904	612	372	316
20.0			560	374	198	208
50.0			288	204	117	94
0.5	T-E	12600	* 7800	* 4280	* 3320	* 4240
1.0		10600	5500	* 3340	* 2480	* 2800
2.5		6000	5120	1960	* 1408	1760
5.0		4280	1960	1160	880	820
10.0		2460	1420	780	490	410
20.0		1450	755	470	265	215
50.0		600	316	240	146	118

TABLE 7

Comparison of Results of Indicated Viscosity of MEX Measured
3 and 7 Days after Production (T-D Spindle, 20 ± 2°C, 3 Readings)

Spindle Speed (rpm)	After 3 Days Viscosity (Pa.s)	After 7 Days Viscosity (Pa.s)
0.5	4181	3893
1.0	2811	2853
2.5	1472	1440
5.0	939	869
10.0	568	536
20.0	344	319
50.0	155	154
Average Temperature of Sample During Measurements	19.7°C	21.6°C

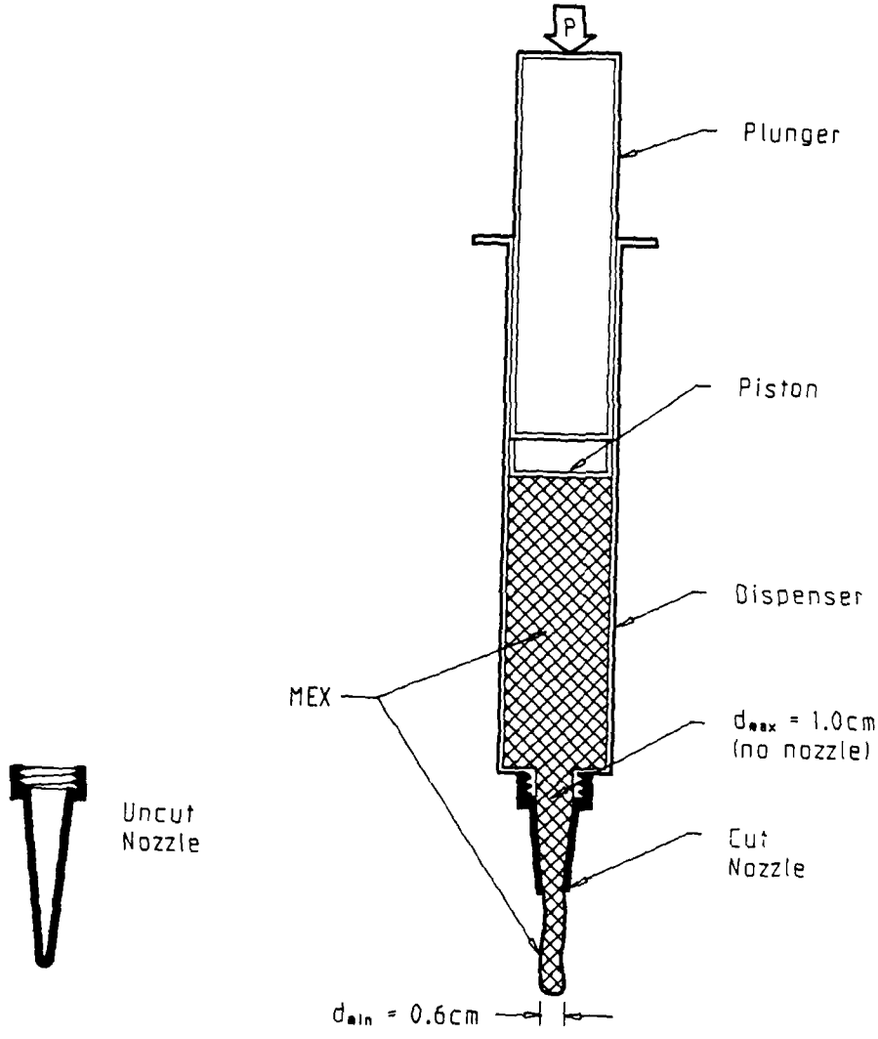

FIGURE 1 Extrusion of MEX from a dispenser.

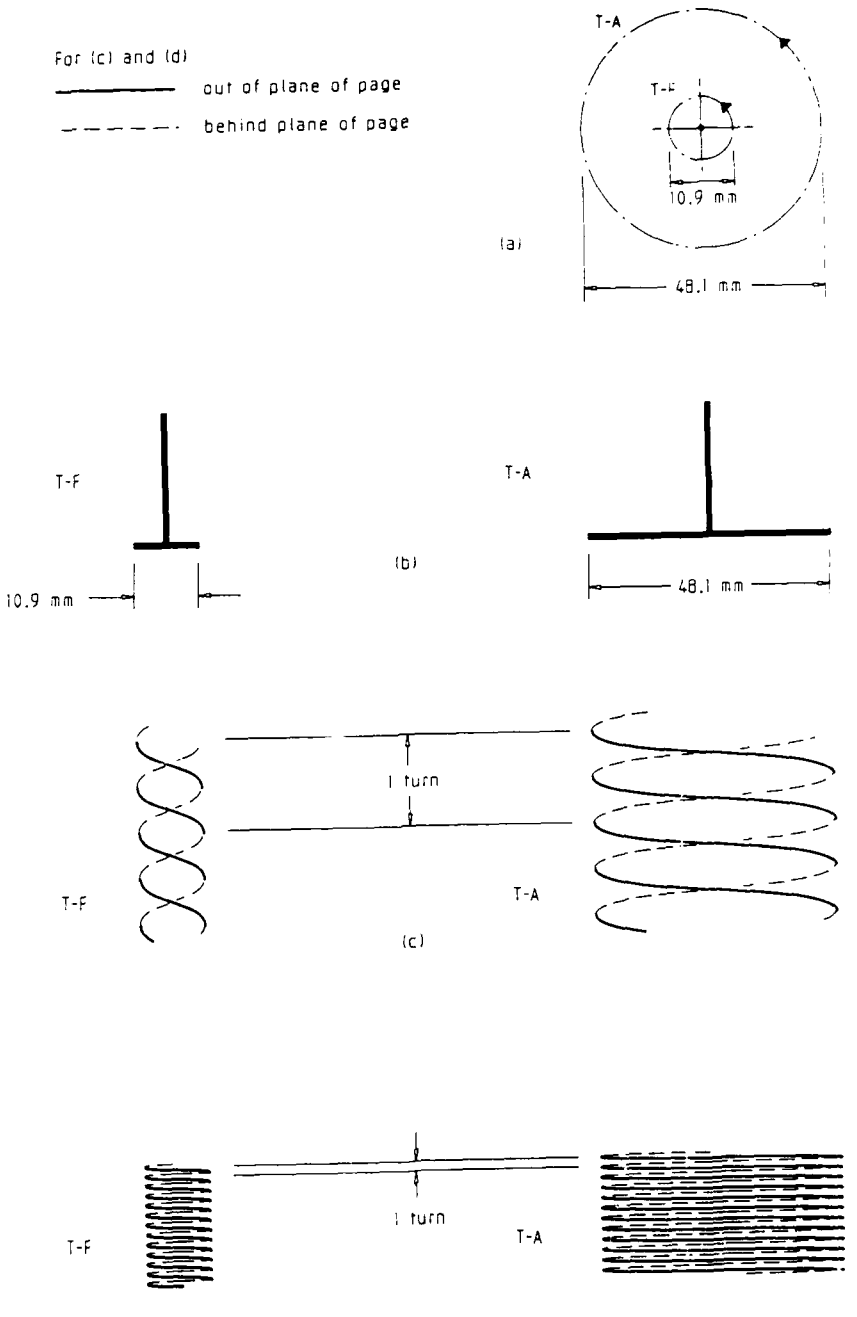

FIGURE 2 Schematic paths of tips of T-F and T-A spindles used with the Brookfield viscometer showing (a) top view, (b) side view of spindles at rest, (c) side view at 0.5 rpm with Helipath stand and (d) side view when speed is increased to 5 rpm (path of only one end of spindle shown in (d)).

APPENDIX 1

ANNEX G TO DRAFT DEF(AUST) DECEMBER 1983 DRAFT

VISCOSITY, HELICAL PATH T-BAR VISCOMETRY

G1 PRINCIPLE

G1.1 The viscosity of the LVPE is tested to ensure it has the correct consistency at 20 ± 2°C.

G2 APPARATUS

Brookfield Viscometer Model RVT with T-F Spindle and Helipath Stand

G3 PROCEDURE

G3.1 Transfer three samples of LVPE into 100 mL beakers. Set viscometer to 20 rpm.

G3.2 Lower the T-F spindle until the T-bar is covered by material. Switch off.

G3.3 Switch on motor to spindle and allow spindle to complete one revolution.

G3.4 Switch on motor to helipath stand and record constant reading.

G3.5 Complete three readings.

G4 EXPRESSION OF RESULTS

Viscosity = Reading x Instrument Factor x Conversion Factor in Pa.s.

Acceptable range: 100-200 Pa.s.

APPENDIX 2

ANNEX G TO DRAFT DEF(AUST) JANUARY 1988 DRAFT

VISCOSITY, HELICAL PATH T-BAR VISCOMETRY

G1 PRINCIPLE

G1.1 The viscosity of the MEX is tested to ensure it has the correct consistency at 20 ± 2°C. If laboratory is outside this temperature range sample should be conditioned in a controlled temperature bath for at least 3 hours.

G2 APPARATUS

Brookfield Viscometer Model HBTD with T-C Spindle and Helipath Stand. T-C Spindle engraved at 30 mm from bottom.

G3 PROCEDURE

G3.1 Transfer three samples of MEX of height 45 mm into plastic jars of 100 mm diameter. Set viscometer to 20 rpm.

G3.2 Lower the T-C spindle until the T-bar is covered by material. Switch off.

G3.3 Switch on motor to spindle and allow spindle to complete one revolution.

G3.4 Switch on motor to helipath stand and record reading when spindle is at 30 mm depth.

G3.5 Complete three readings.

G4 EXPRESSION OF RESULTS

Viscosity = Reading x Instrument Factor x Conversion Factor in Pa.s.

Acceptable Range: 100-180 Pa.s.

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Viscosity measurements of malleable explosive (MEX), a new demolition explosive

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ABSTRACT

The rheological characterisation of Malleable Explosive (MEX), a new explosive intended for demolition use, is presented. A Brookfield viscometer with T-bar spindles and Helipath stand is used to investigate the viscosity of MEX at shear rates similar to those encountered during extrusion of the material from a dispenser. The indicated viscosity is sensitive to the position, type and speed of spindle used for the determination. The viscosity is determined over the temperature range -16°C to 60°C and is particularly temperature sensitive only below 0°C, whereupon the viscosity rises rapidly. From 0°C to 40°C, the viscosity decreases to a value which is dependent upon the temperature and shear rate, then remains constant or increases slightly with further heating to 60°C. A laboratory method suitable for transfer to the production factory in the event that MEX proceeds to full production, is detailed.